



Single-particle characterization of ice-nucleating particles and ice particles residuals sampled by three different techniques

Konrad Kandler (1), Annette Worringen (1,7), Nathalie Benker (1), Thomas Dirsch (1), Stephan Mertes (2), Ludwig Schenk (2), Udo Kästner (2), Fabian Frank (3), Björn Nillius (3,6), Ulrich Bundke (3,*), Diana Rose (3), Joachim Curtius (3), Piotr Kupiszewski (4), Ernest Weingartner (4,+), Paul Vochezer (5), Johannes Schneider (6), Susan Schmidt (6), Stephan Weinbruch (1), and Martin Ebert (1)

(1) Institut für Angewandte Geowissenschaften, Technische Universität Darmstadt, Schnittspahnstr. 9, 64287 Darmstadt, Germany, (2) Leibniz-Institut für Troposphärenforschung, Permoserstraße 15, 04318 Leipzig, Germany, (3) Institut für Atmosphäre und Umwelt, Goethe-Universität Frankfurt am Main, Altenhöferallee 1, 60438 Frankfurt am Main, Germany, (4) Laboratory of Atmospheric Chemistry, Paul Scherrer Institute, 5232 Villigen PSI, Switzerland, (5) Institute for Meteorology and Climate Research, Karlsruhe Institute of Technology, P.O. Box 3640, 76021 Karlsruhe Germany, (6) Max-Planck-Institute für Chemie, Hahn-Meitner-Weg 1, 55128 Mainz, Germany, (7) Institut für Physik der Atmosphäre, Johannes Gutenberg Universität Mainz, 55099 Mainz, Germany, (*) now at: Forschungszentrum Juelich GmbH, 5245 Juelich, (+) now at: University of Applied Sciences and Arts Northwestern Switzerland, School of Engineering, Institute of Aerosol and Sensor Technology, Klosterzelgstrasse 2, 5210 Windisch, Switzerland

During January/February 2013, at the High Alpine Research Station Jungfraujoch a measurement campaign was carried out, which was centered on atmospheric ice-nucleating particles (INP) and ice particle residuals (IPR). Three different techniques for separation of INP and IPR from the non-ice-active particles are compared. The Ice Selective Inlet (ISI) and the Ice Counterflow Virtual Impactor (Ice-CVI) sample ice particles from mixed phase clouds and allow for the analysis of the residuals. The combination of the Fast Ice Nucleus Chamber (FINCH) and the Ice Nuclei Pumped Counterflow Virtual Impactor (IN-PCVI) provides ice-activating conditions to aerosol particles and extracts the activated INP for analysis. Collected particles were analyzed by scanning electron microscopy and energy-dispersive X-ray microanalysis to determine size, chemical composition and mixing state. All INP/IPR-separating techniques had considerable abundances (median 20 – 70 %) of instrumental contamination artifacts (ISI: Si-O spheres, probably calibration aerosol; Ice-CVI: Al-O particles; FINCH+IN-PCVI: steel particles). Also, potential sampling artifacts (e.g., pure soluble material) occurred with a median abundance of < 20 %. While these could be explained as IPR by ice break-up, for INP their IN-ability pathway is less clear. After removal of the contamination artifacts, silicates and Ca-rich particles, carbonaceous material and metal oxides were the major INP/IPR particle types separated by all three techniques. Soot was a minor contributor. Lead was detected in less than 10 % of the particles, of which the majority were internal mixtures with other particle types. Sea-salt and sulfates were identified by all three methods as INP/IPR. Most samples showed a maximum of the INP/IPR size distribution at 400 nm geometric diameter. In a few cases, a second super-micron maximum was identified. Soot/carbonaceous material and metal oxides were present mainly in the submicron range. ISI and FINCH yielded silicates and Ca-rich particles mainly with diameters above 1 μm , while the Ice-CVI also separated many submicron IPR. As strictly parallel sampling could not be performed, a part of the discrepancies between the different techniques may result from variations in meteorological conditions and subsequent INP/IPR composition. The observed differences in the particle group abundances as well as in the mixing state of INP/IPR express the need for further studies to better understand the influence of the separating techniques on the INP/IPR chemical composition.